Automated Satellite-Imager Based Hazardous Storm Cell Detection Products

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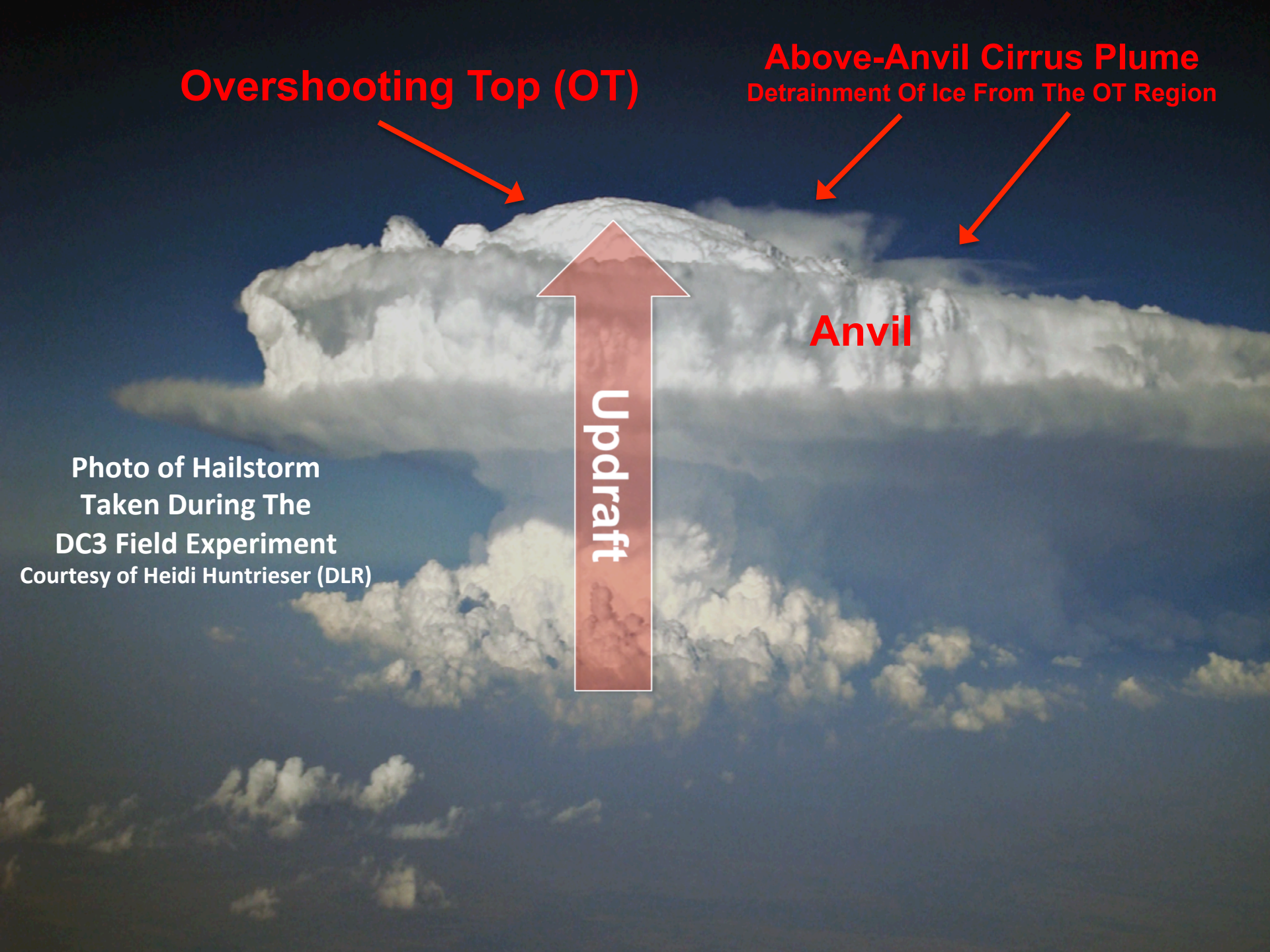
Introduction

- Hazardous storms produce a unique signature called an overshooting cloud top in satellite-observed reflected sunlight ("visible") and infrared imagery
- Automated satellite-based methods for detecting hazardous storms have been developed at NASA Langley Research Center (LaRC), supported by both NASA and NOAA
- NASA LaRC has immediate access to the Himawari-8 satellite imagery collected at 10 minute intervals over Southeast Asia. Himawari-8 is currently the operational geostationary satellite that observes Southeast Asia
- This enables detection of hazardous storms at 2 km resolution and distribution of easy-to-understand products to users within minutes of the satellite image
- The combination of these capabilities allows for real-time awareness and forecasting of hazardous storms anywhere and at any time an image is available. This is especially valuable in regions without radar or lightning detection data like most of SE Asia
- Recent NASA story on LaRC hazardous storm research:

http://www.nasa.gov/feature/langley/nasa-researchers-improve-hazardous-weather-forecasts


Overshooting Top (OT)
Above-Anvil Cirrus Plume
Detrainment Of Ice From The OT Region
Anvil
Updraft
Photo of Hailstorm
Taken During The
DC3 Field Experiment
Courtesy of Heidi Huntrieser (DLR)

Overshooting Top (OT)

Above-Anvil Cirrus Plume
Detrainment Of Ice From The OT Region

Updraft

Anvil

Weather Hazards Concentrated Near Overshooting Tops

- Tornadoes
- Hail
- Damaging wind
- Lightning
- Heavy Rainfall
- Aircraft icing
- Turbulence

Photo of Hailstorm
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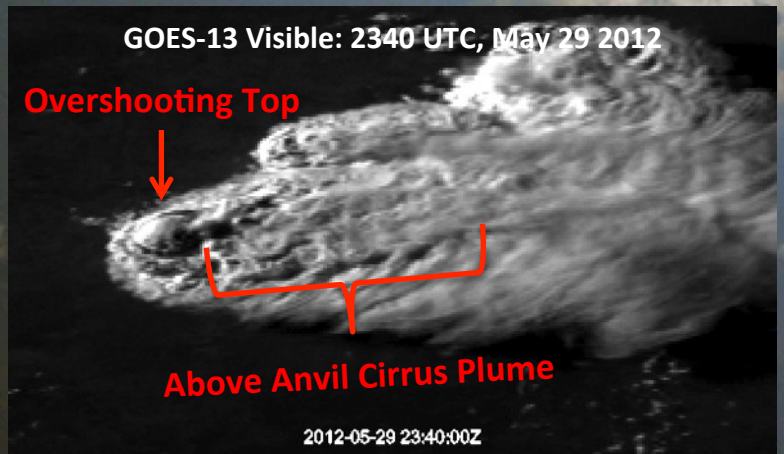
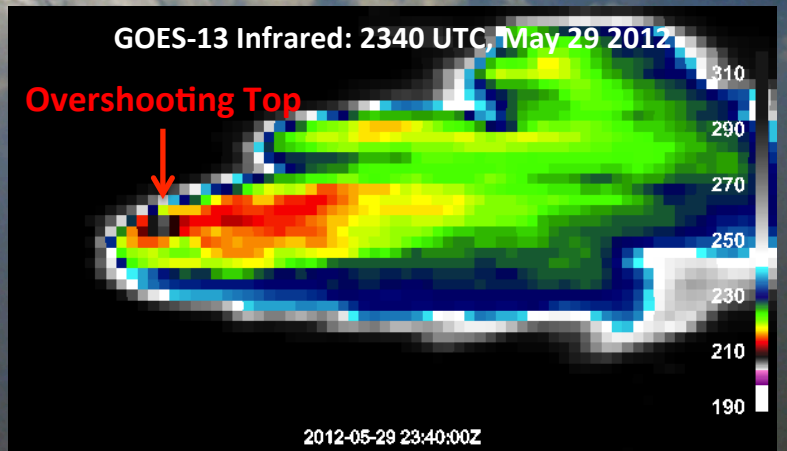
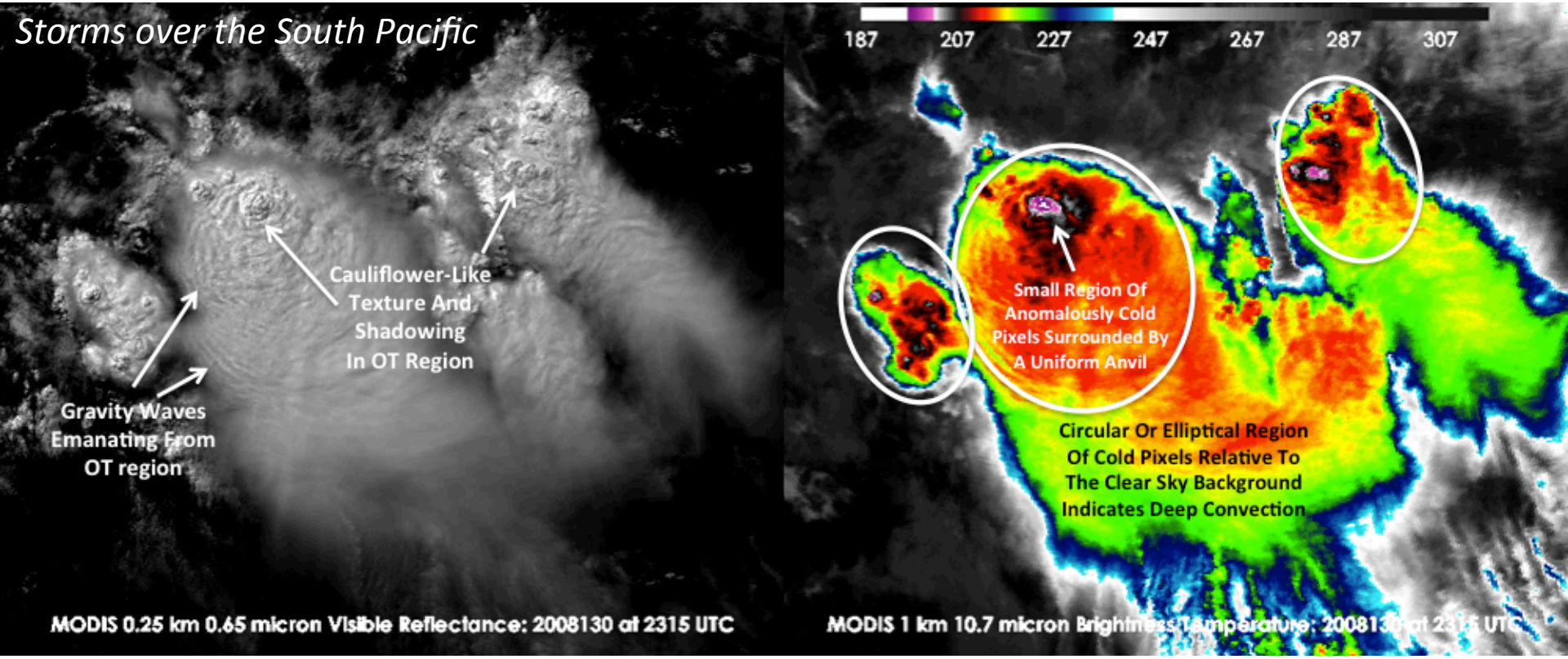




How Do Our Human Minds Identify Hazardous Storms in Satellite Imagery?



How Can A Computer Algorithm Emulate The Human Mind?

- Satellite data are simply 2-D arrays of data representing reflected sunlight or IR emission at particular wavelengths
- What is an “anvil” cloud or an OT? Based on reflectance or temperature value? Something more complex?
- How to quantify “texture”?
- ***We need to transform what we take for granted in our minds into computer code that can reliably detect hazardous storms anywhere at any time***

Visible and IR-Based Probabilistic Overshooting Cloud Top Detection

GOAL: Mimic the human overshooting top (OT)detection process using IR & visible imagery and NWP data within an automated computer algorithm

Satellite IR and Visible OT Indicators Derived Via Image Pattern Recognition + NWP Fields

↓

Large Global Training Database of Satellite + NWP Fields For Both OT and Non-OT Anvil Regions

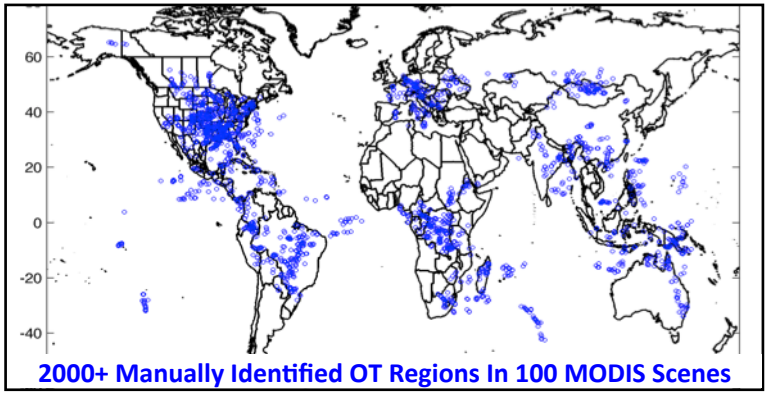
↓

Statistical Model Used To Discriminate Between The OT and Non-OT Anvil Populations

↓

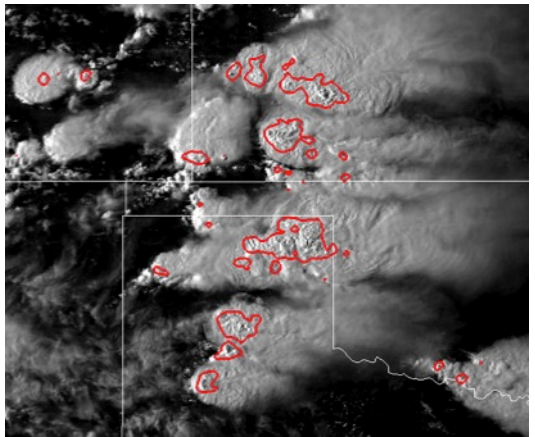
IR+NWP OT Probability Product

+ Visible Texture Detection



2000+ Manually Identified OT Regions In 100 MODIS Scenes

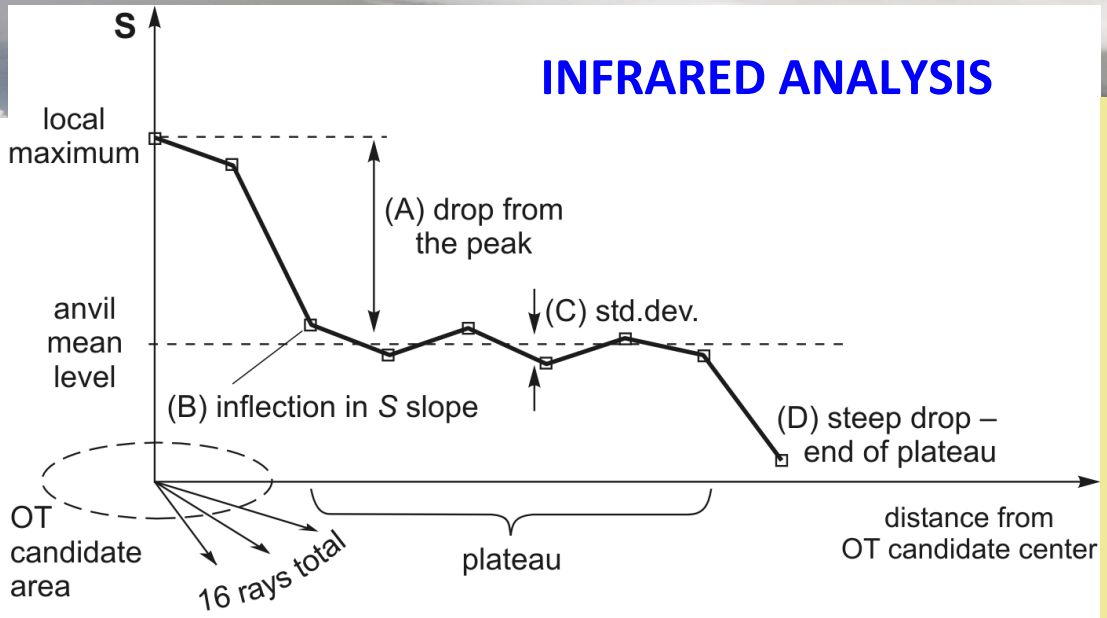
Automated Satellite-Based Hazardous Storm Detections (red) Overlaid on GOES Visible Satellite Imagery



Overshooting Top Pattern Recognition Analyses

Bedka and Khlopenkov (JAMC, In Press, 2016)

INFRARED ANALYSIS



Normalize IR BT relative to regional clear-sky BT characteristics to identify deep convection

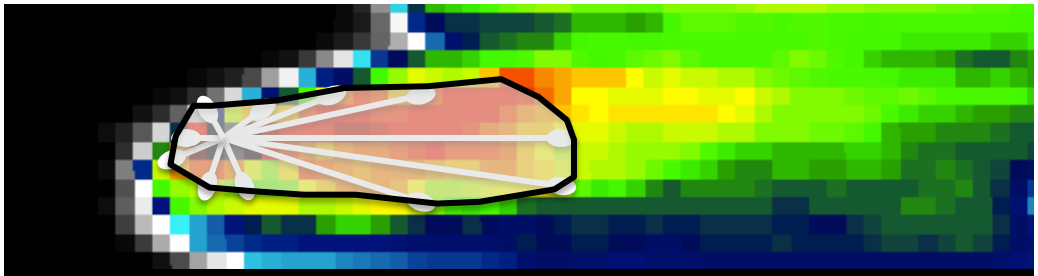
Pattern recognition used to ensure that 1) the region being analyzed is indeed within deep convection and 2) the feature of interest has characteristics typical of OTs

Pattern recognition uses

- OT shape correlation
- BT Score prominence relative to surrounding anvil
- Anvil flatness, roundness, and edge sharpness

The net result is a cumulative rating obtained for each possible OT region. Pixels with a non-zero rating are considered "OT Candidate" regions

OT Candidates are then assigned an OT Probability based on BT comparison with anvil mean BT, NWP tropopause, and equilibrium level temps using a large training database of human-identified OT and non-OT regions

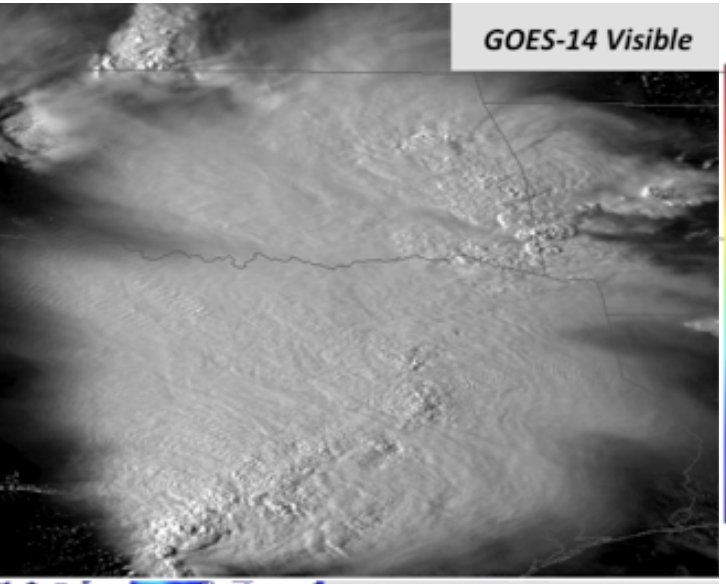


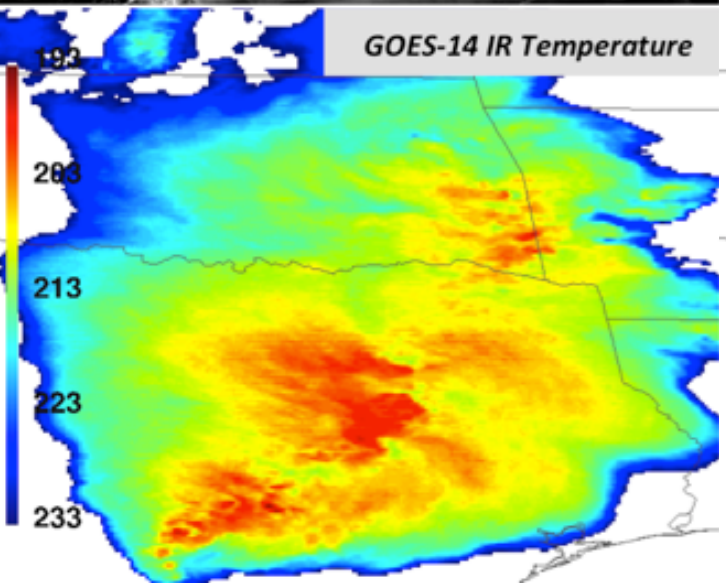
Identify spatial extent of anvil cloud and determine how far OT candidate regions penetrate above their anvils

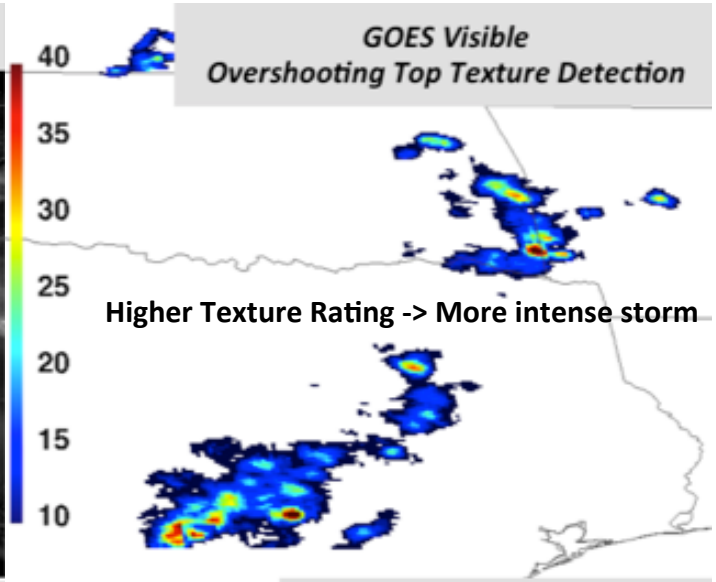
VISIBLE ANALYSIS

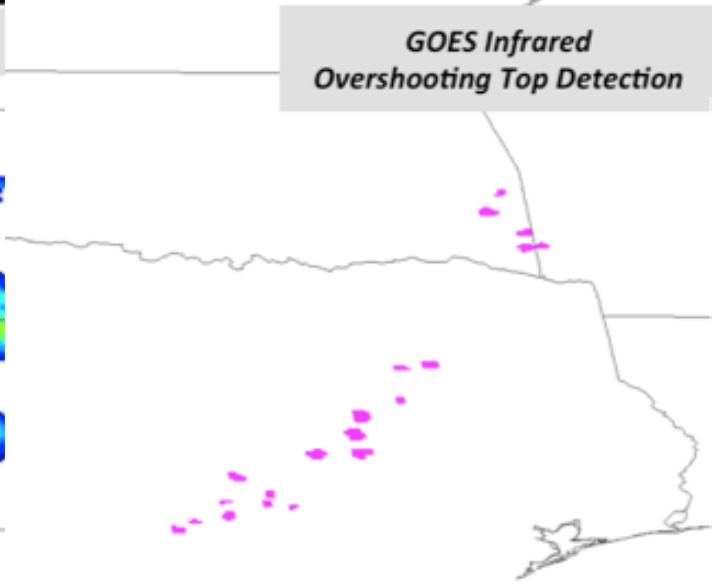
- **Identify anvil clouds by spatial analysis and thresholding of visible reflectance as a function of time of day and day of year**
- **Quantify texture via pattern recognition within Fourier transform computed in small windows in anvils**
- **Detect OT-induced shadows at high solar zenith angle**

NASA LaRC Satellite-Based Overshooting Top Detection Products









GOES satellite image covering the US can be processed and distributed to users within 3 mins of image acquisition at LaRC

Visible+IR Product
POD/FAR =51 / 2%

IR Only Product
POD/FAR = 69 / 18%

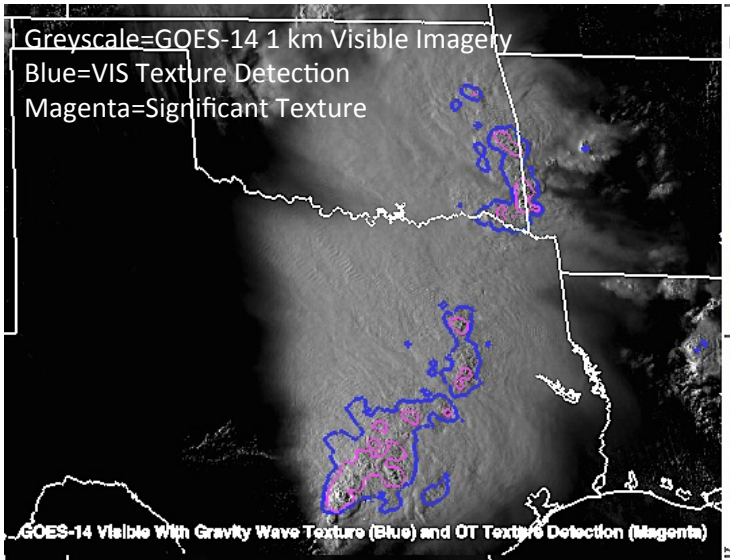
Product output can be tailored to meet user needs

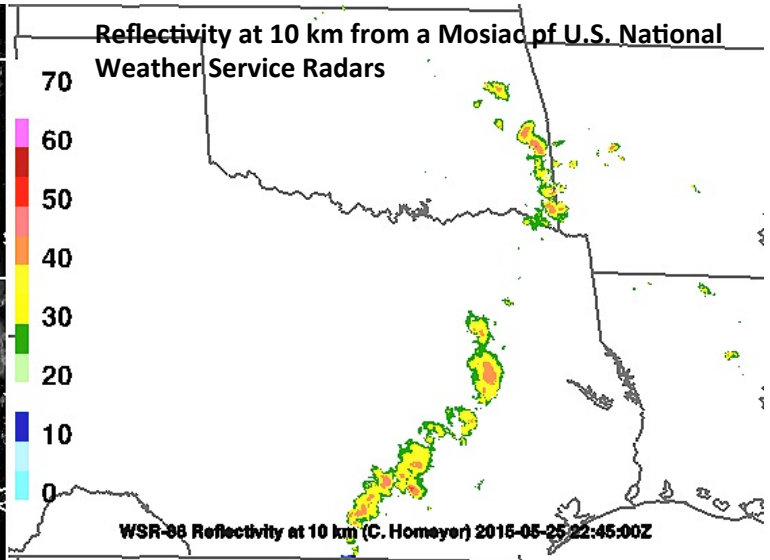
Weather Hazards Concentrated Near Overshooting Tops

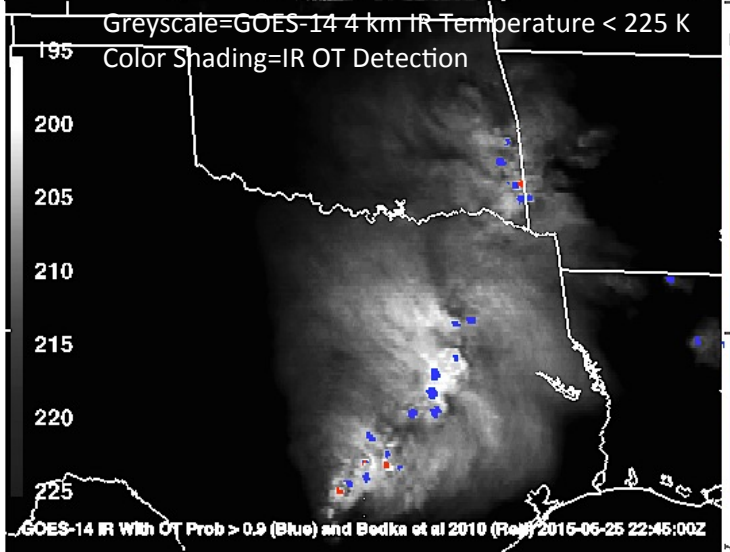
- Tornadoes
- Hail
- Damaging wind
- Lightning
- Heavy Rainfall
- Aircraft icing
- Turbulence

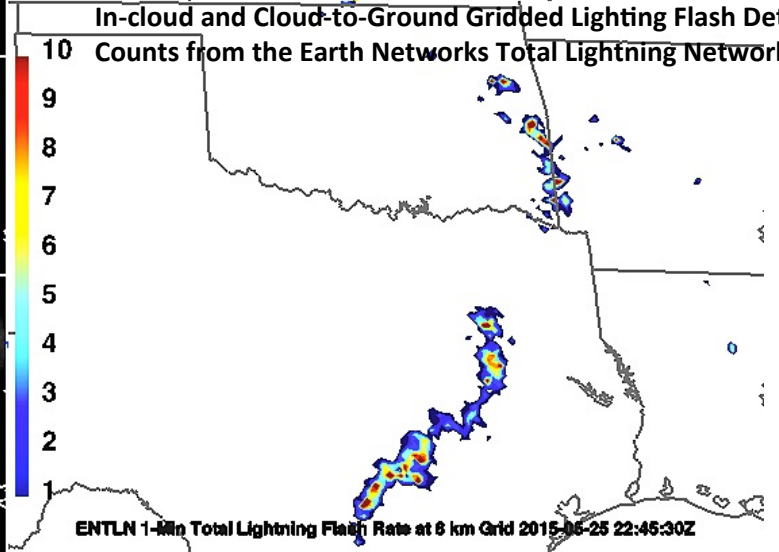
Multi-sensor Hazardous Storm Detection
GOES-14 Super Rapid Scan: 25 May 2015

ANIMATION AVAILABLE HERE: http://cloudsgate2.larc.nasa.gov/site/people/data/kbedka/OTDetection_mutlipanel.gif

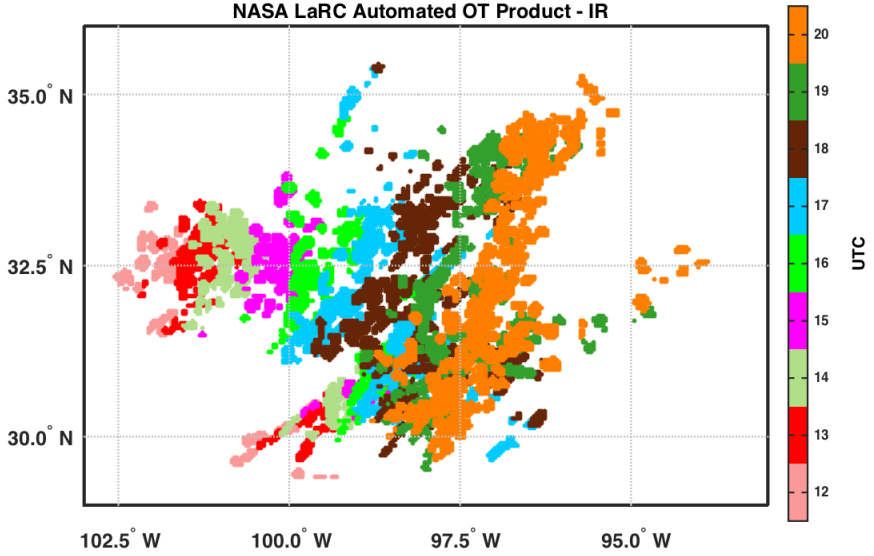




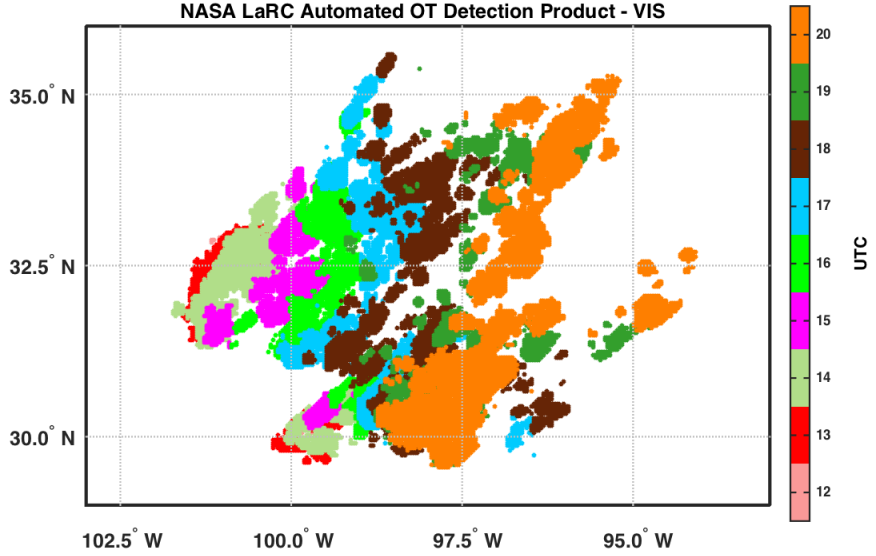




IR-Based OT Detection

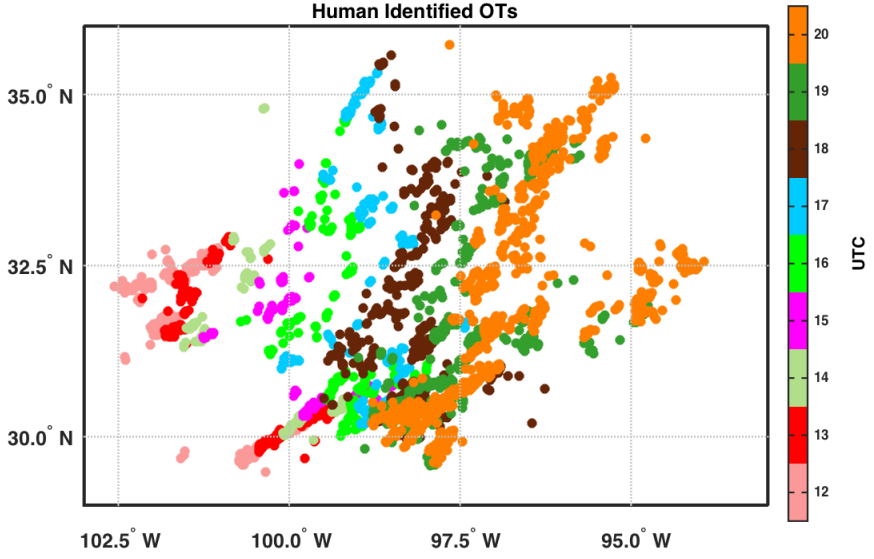


Visible OT Texture Detection

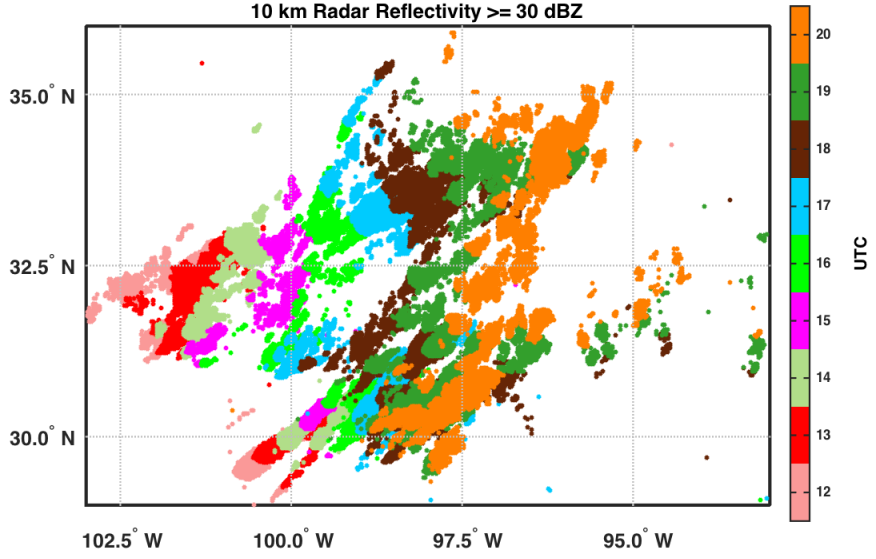


25 MAY 2015: 1200-2100 UTC

Human OT Identifications

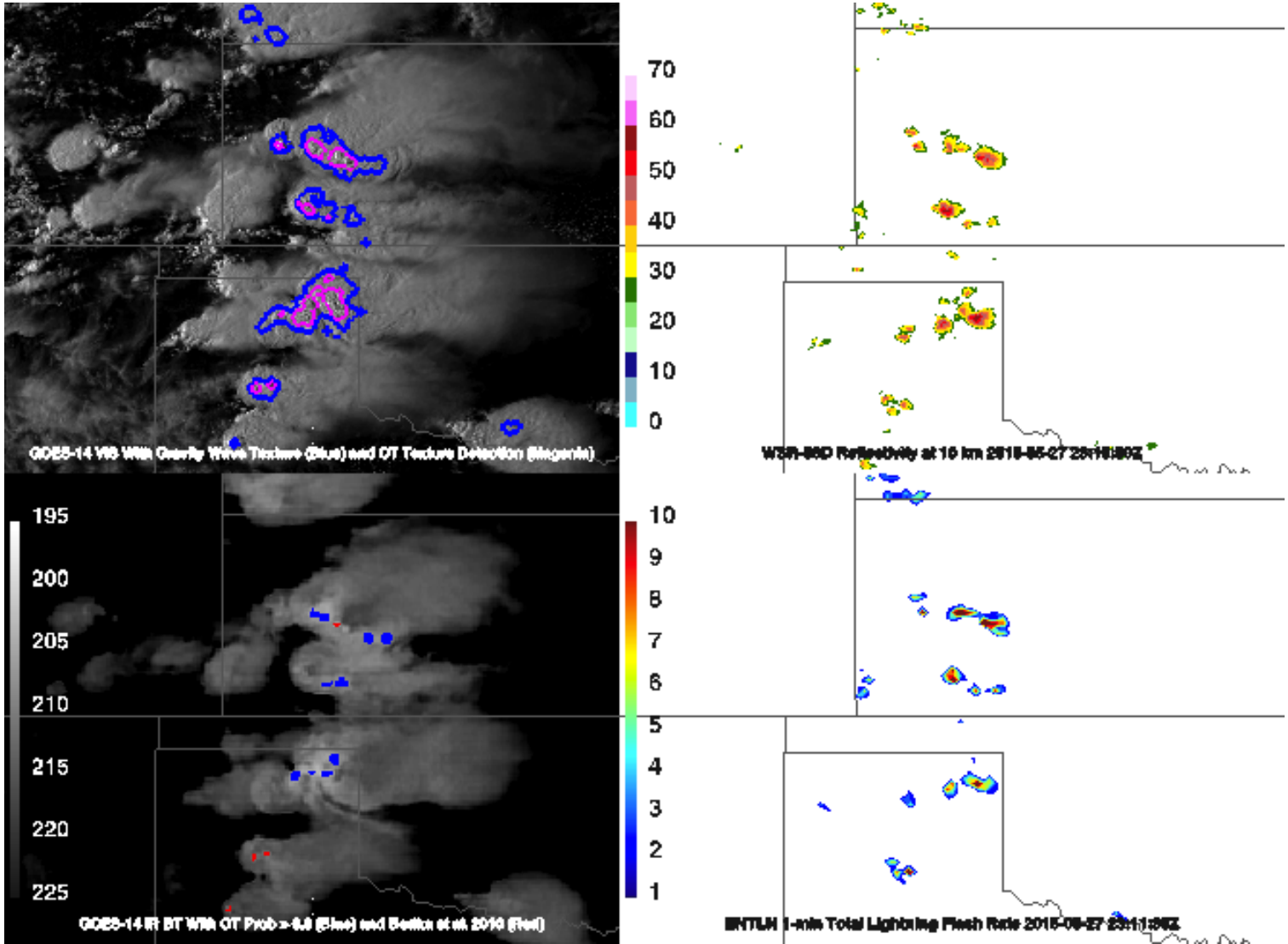


10 km Radar Reflectivity > 30 dBZ



Multi-sensor Hazardous Storm Detection Animation
GOES-14 Super Rapid Scan: 27 May 2015

ANIMATION AVAILABLE HERE: http://cloudsgate2.larc.nasa.gov/site/people/data/kbedka/MAY27_OTDetection_mutlipanel.gif



Detection of Hazardous Storms Over Southeast Asia Using Himawari-8
13 June 2015

Record breaking winds claim lives in Hanoi, Vietnam

Posted by Elena Ugrin on June 15, 2015 in categories Featured articles, Severe storms

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[Video] 2 Dead, 1,000 Trees Uprooted As Historic Storm Rocks Hanoisgnr.co/1L9FGlP#Hanoi #storm #dead

11:48 PM - 14 Jun 2015

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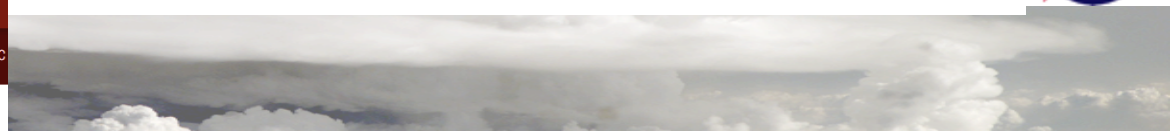
Detection of Hazardous Storms Over Southeast Asia Using Himawari-8
13 June 2015



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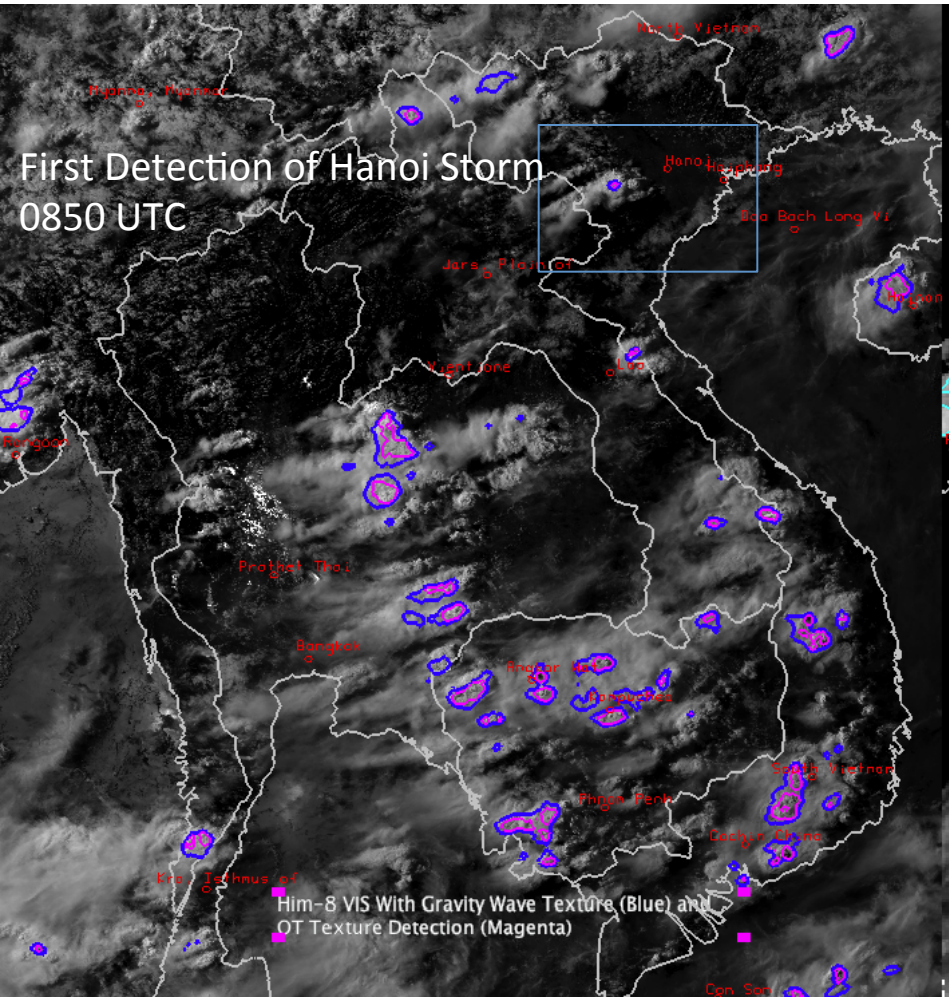

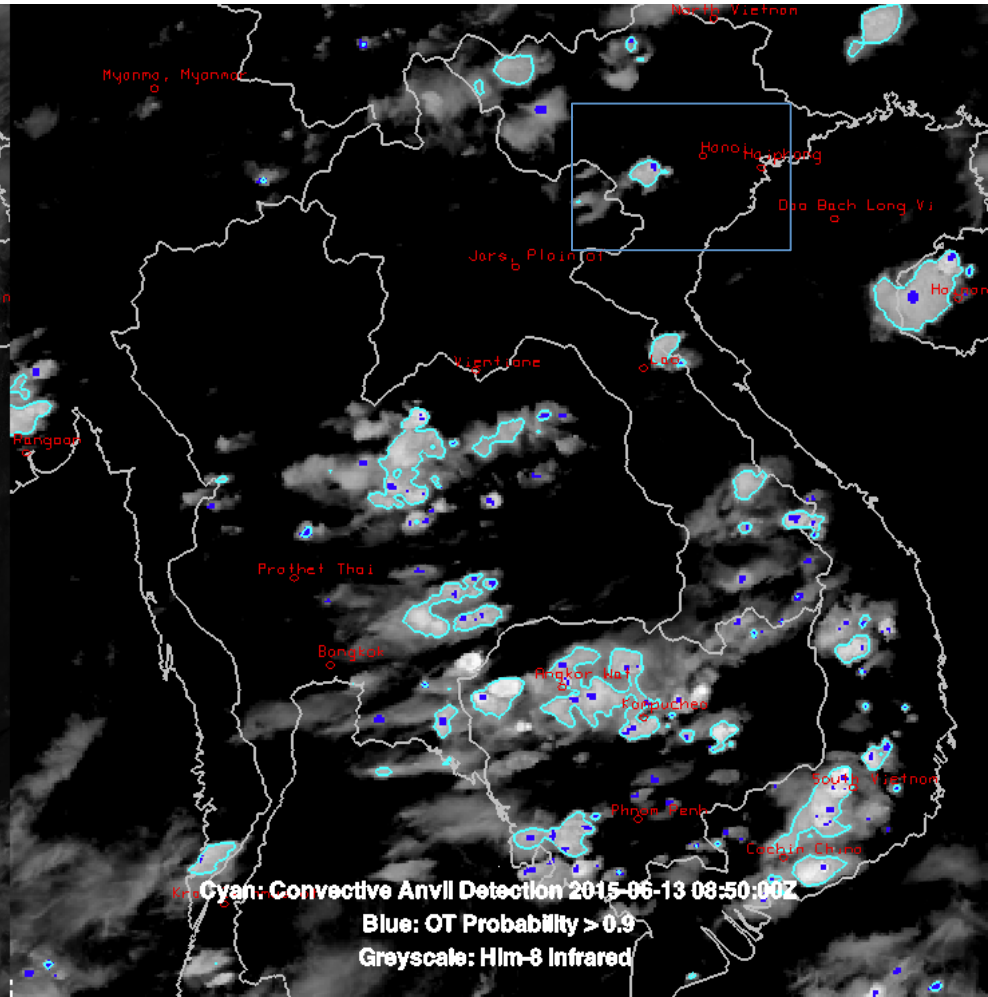

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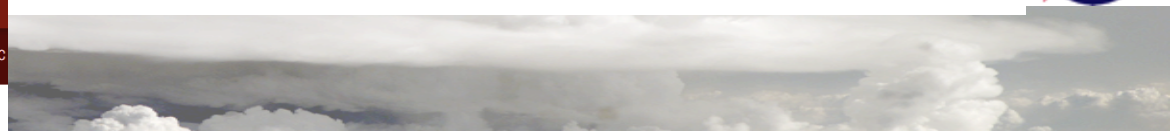

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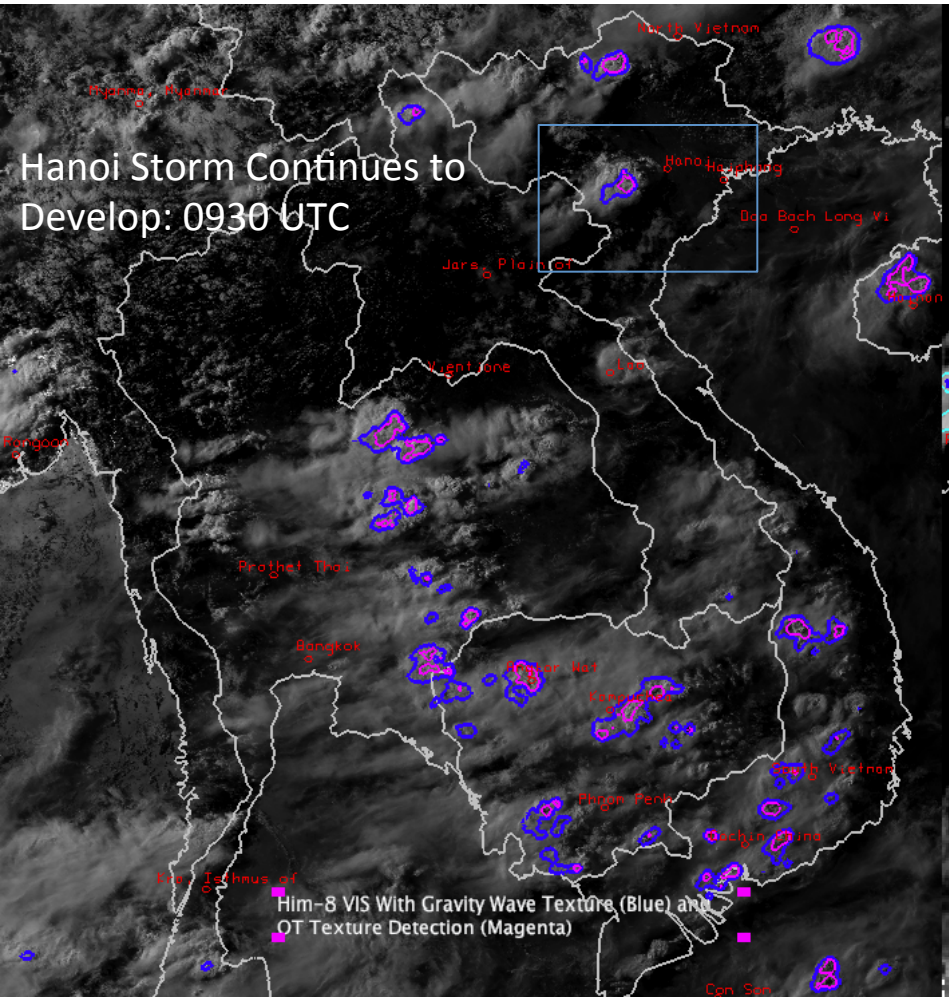

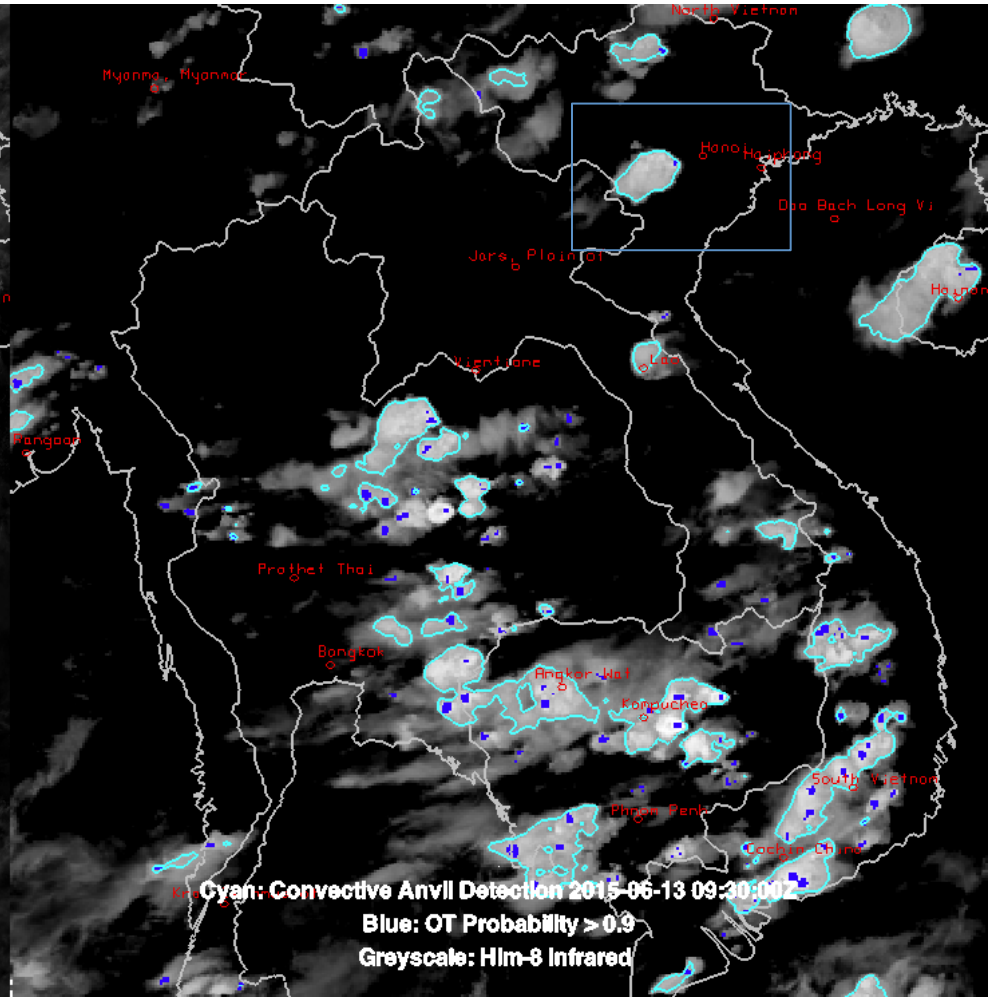

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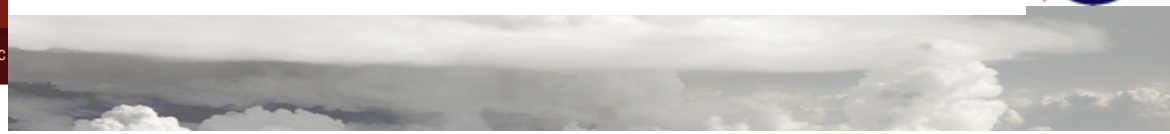

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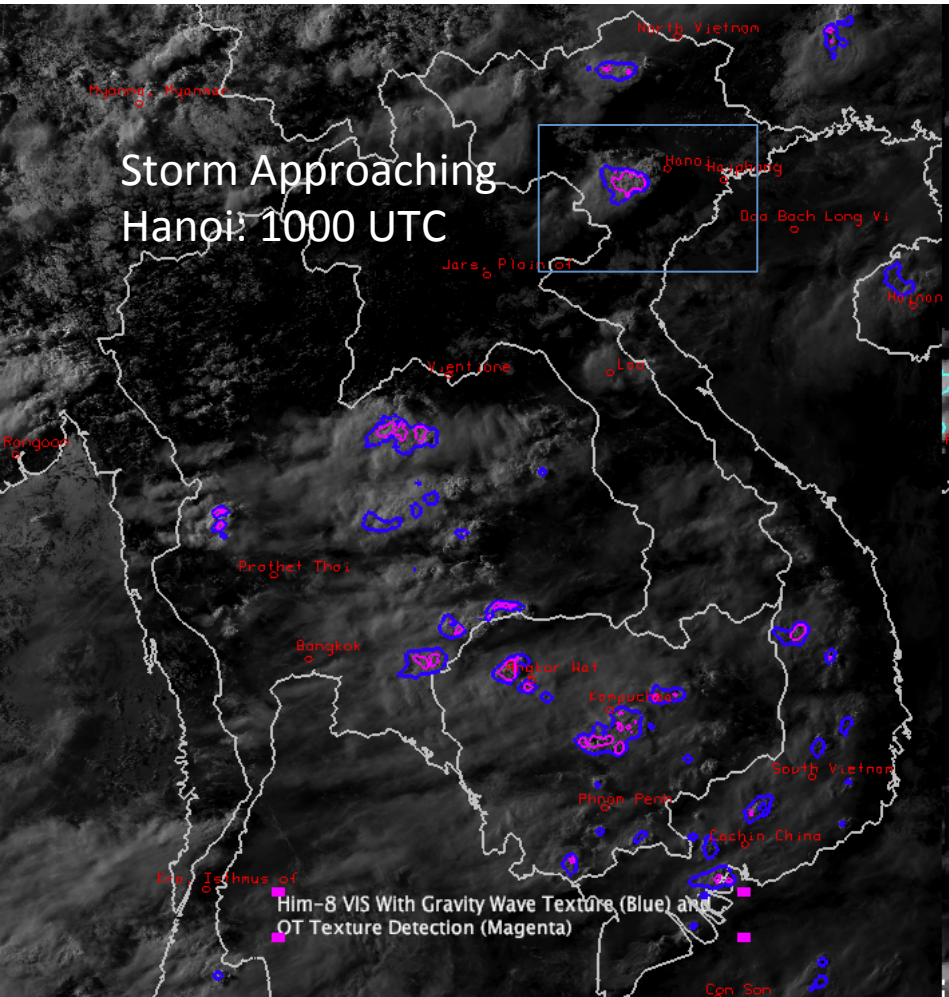

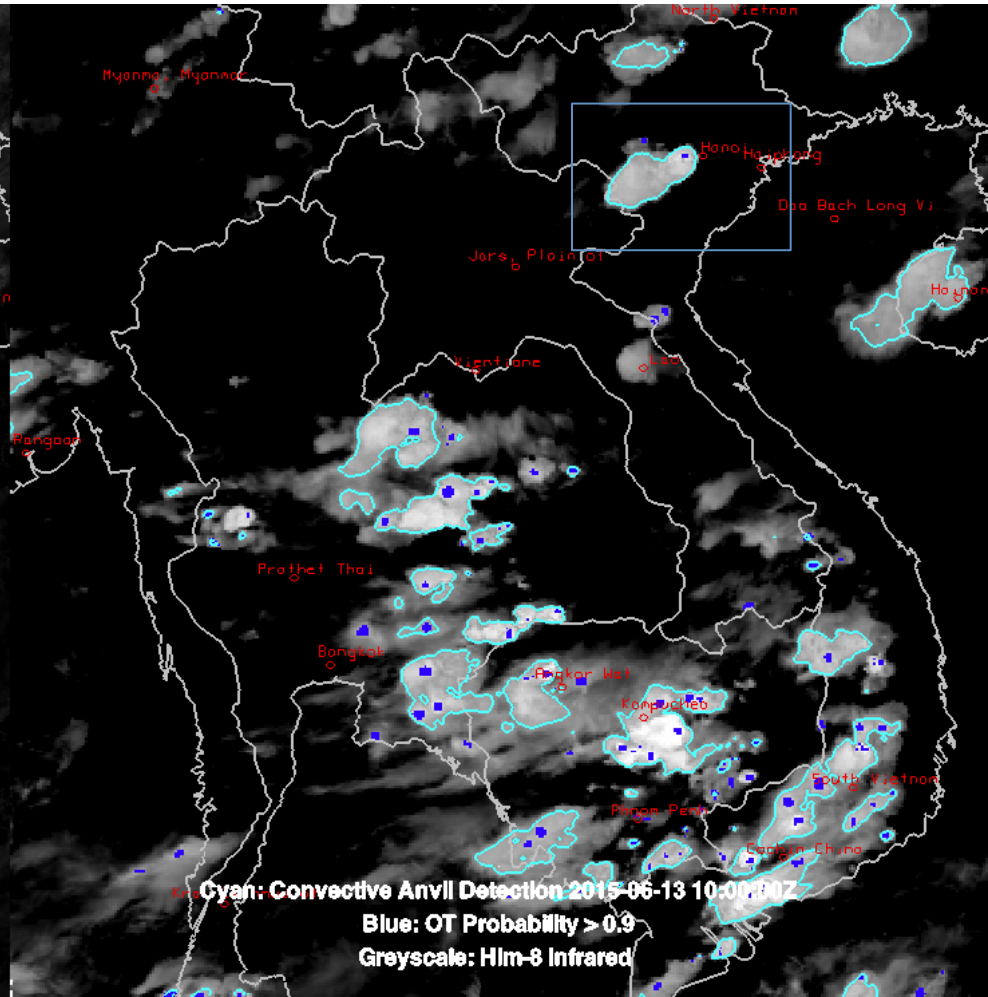

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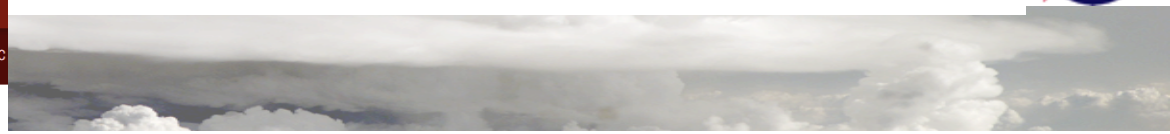

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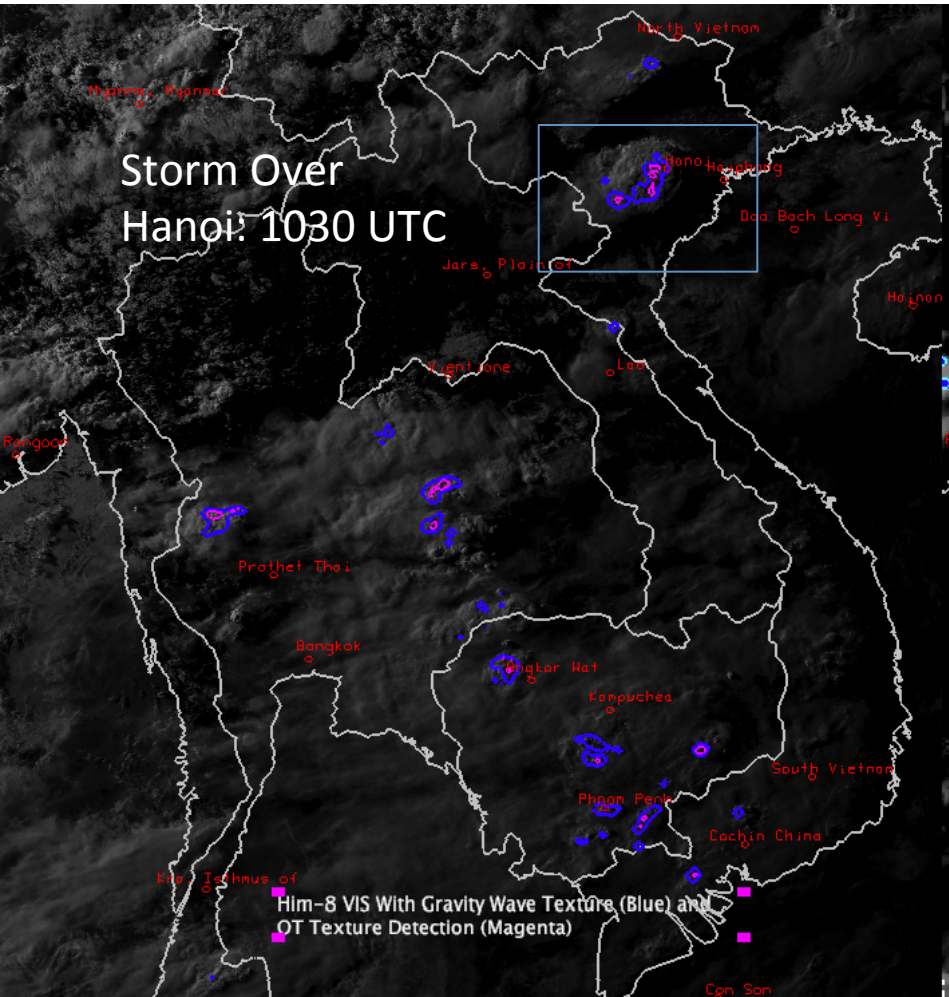
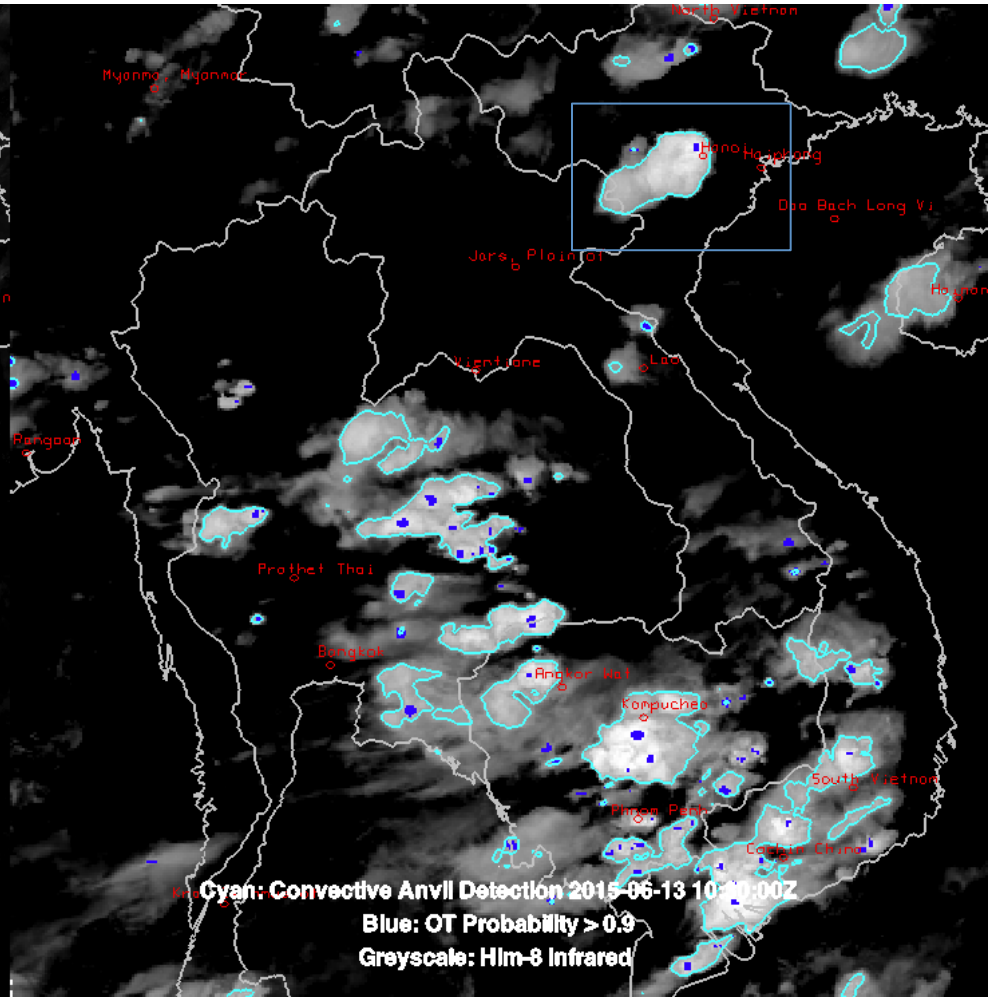
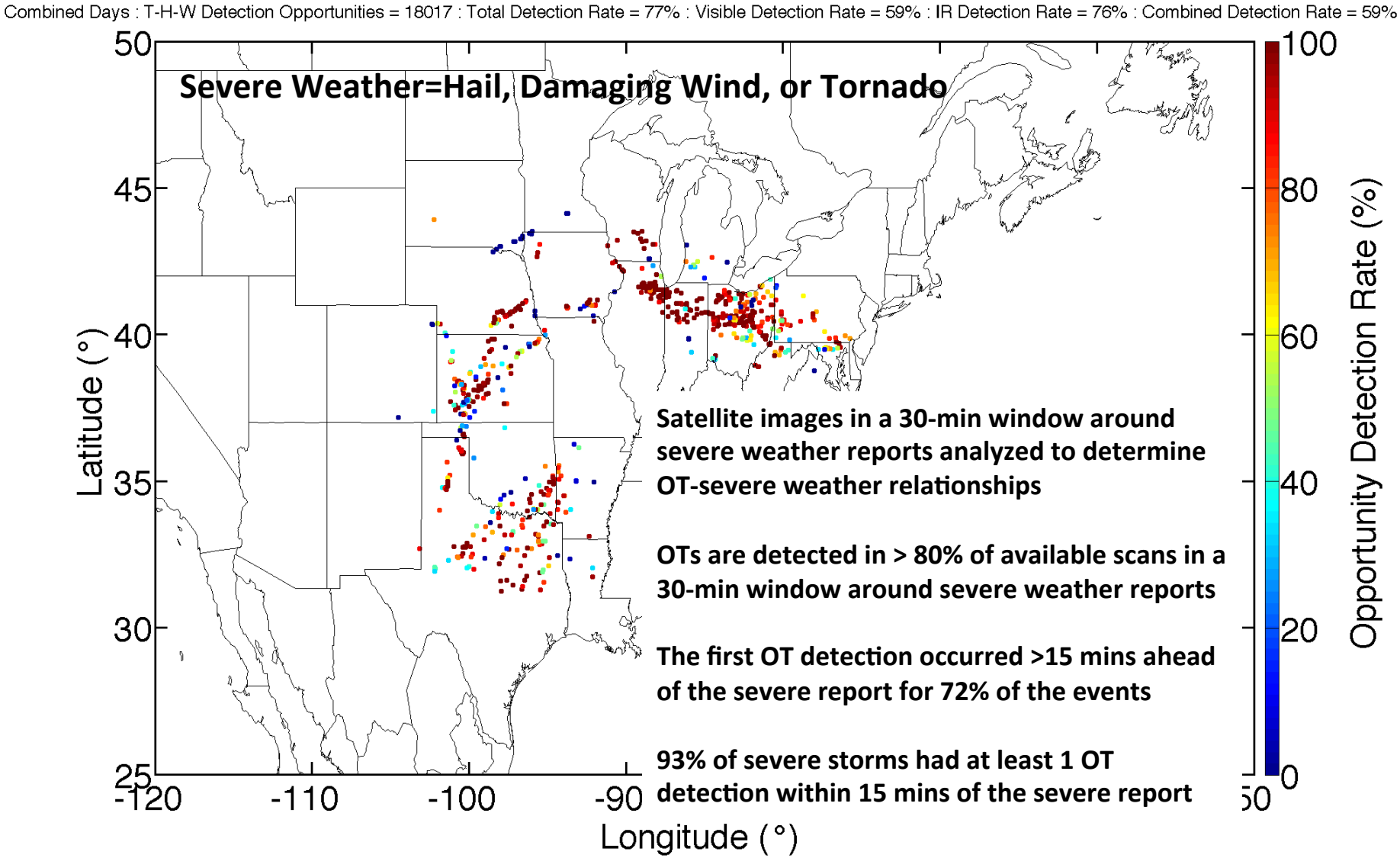


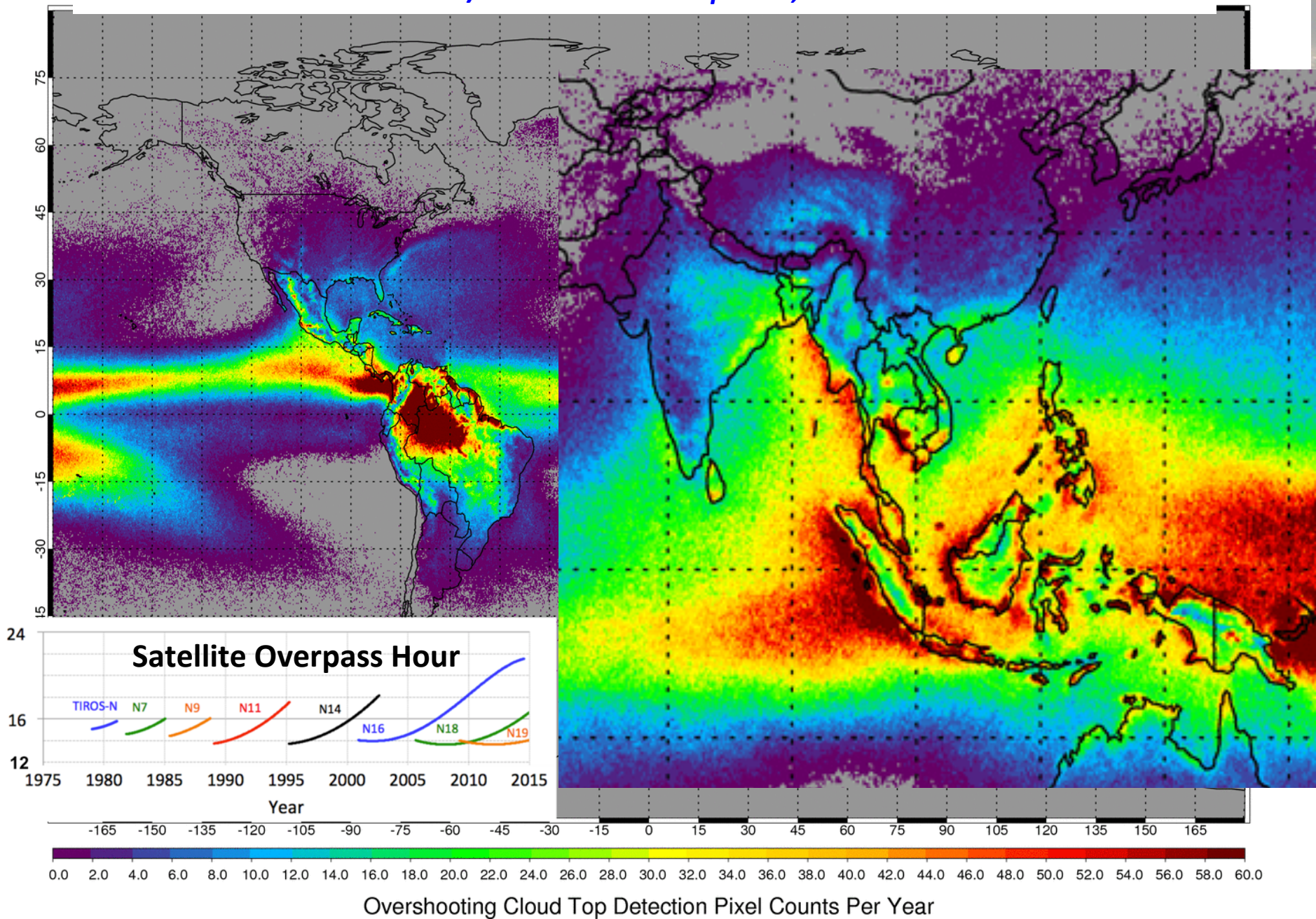


Overshooting Top - Severe Weather Relationships Using GOES-14 1-Minute Super Rapid Scan Imagery



33-Year AVHRR Overshooting Top Climatology

"230 AM/PM" Satellite Overpasses, 0.25° Grid



QUESTIONS AND DISCUSSION